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PROBLEMS OF FOAM GLASS PRODUCTION

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Principles of producing foam glass rate considered. A correlation between structure and such properties as density, water absorption, strength, and thermal conductivity of materials obtained is demonstrated. The advantages, disadvantages, and prospects of a "cold" method for foam glass production are discussed.

Contemporary civil engineering uses diverse materials developed on the basis of ceramics, binders, and glass. Heat-insulating materials that are capable of effectively saving power resources consumed in providing required temperature conditions in interiors are acquiring increasing significance. Such materials have to satisfy numerous requirements with respect to their thermophysical, fire safety, and service parameters.

Foam glass to the maximum extent satisfies all requirements imposed. A method for production of this material was developed as early as the end of 1930s by I. I. Kitaigorodskii (USSR) and B. Long (France). Unfortunately, despite obvious advantages of foam glass it did not find wide application. However, interest in this material in our country has been growing lately.

Foam glass is porous a heat-insulating and soundproof material, with true porosity up to 90 – 97%. In its physical aspect, foam glass is a heterophase system consisting of the gaseous and the solid phases. The solid phase is glass that forms thin walls of single cells several micrometers thick. The cells are filled with the gaseous phase, in which gas pressure at room temperature is approximately 30.3 – 40.5 kPa.

Depending on destination, heat-insulating and soundproof foam glass can have predominantly sealed or communicating pores, respectively. The demand for heat-insulating foam glass is significantly higher than for soundproof glass. Besides, foam glass of special destination (high-temperature, chemically resistant, etc.) is needed in relatively small quantities.

All foam glass is currently produced by the powder method. The essence of this method consists in sintering a mixture of glass powders and special additives facilitating the formation of a gaseous phase in heating. These additives introduced into a foam-glass batch in small quantities are called pore-forming or gas-forming agents. Several processes take place under thermal treatment of such a mixture, resulting in the formation of a foam mixture. When the temperature of the mixture in heating exceeds the softening temperature, glass particles start sintering and form a continuous sintered body. Particles of the pore-forming agent become insulated by softening glass. After a certain temperature is reached, they start emitting gases frothing the glass melt. Due to gas emission, pores emerge in all parts of the sintered body where the particles of the pore-forming agent were blocked. The shape of pores and the properties of foam glass obtained largely depend on the concentration and type of the foaming agent used.

It is generally accepted that foaming agents are of two types: neutralization and redox agents. The first group includes salts (as a rule, carbonates), which in heating decompose with emission of gases (CO_2). Intense gas release during their decomposition breaks the walls of individual pores, which merge and create a maze-like system of cavities in glass. Such foam glass has high water absorption and elevated soundproof parameters.

Redox gas-forming agents are used to produce heat-insulating foam glass, i.e., a material in which sealed pores prevail. Such gas-forming agents are carbon-containing materials: coke, anthracite, soot, graphite, less frequently silicon carbide. The reason for gas emission in these materials is the reaction of oxidation of the foaming agent by gases dissolved in the glass melt. Such gases are primarily oxygen and sulfuric anhydride.

Foam glass with low thermal conductivity surpasses many heat-shielding materials in a number of properties. Foam glass is resistant to water, has relatively high mechanical strength, is incombustible, and satisfies stringent sanitary-hygienic requirements, since it is biologically resistant, i.e., does not putrefy or get moldy. The relatively high mechanical strength of foam glass facilitates installation, and its biological and chemical resistance ensures constancy of its thermal conductivity values with time.

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Foam glass, as a rule, is primarily characterized by density. Contemporary foam glass is ten times lighter than water, its density is around 100 kg/m^3. Besides, the most important service parameters of materials are usually indicated: strength, water absorption, and thermal conductivity. They all depend on the foam glass structure (the size and configuration of pores, their insulated position, thickness of glass walls between the pores) and to a certain extent correlate with density. The higher is porosity and the lower density, the lower is strength, since a load is distributed among a smaller amount of glass. It is hard to say, what yields higher strength: thin and closely spaced walls or sparse walls of greater thickness. With equal density values, either variant is possible.

Water absorption does not have such clear correlation with density. The type of the pore-forming agent and its concentration have a crucial effect on water absorption. The neutralization type of a pore agent ensures open porosity in glass and, accordingly, high water absorption, namely, 50 – 70% and more. The use of redox gas-forming agents ensures the formation of predominantly sealed pores. Such material has low water absorption: 10 – 15%. Water absorption at a level of 0.5% announced by some foreign companies is either an error, or is due to different methods of measuring this property used by researchers. As for a correlation between density and water absorption, it can be said that the lower the density, the harder it is to attain low water absorption,, since having high porosity, it is difficult to reliably separate pores from each other.

Thermal conductivity of foam glass also depends on the type of porosity and this parameter in the case of prevalence of closed pores has a higher value than under prevalence of communicating pores, therefore, foam glass with prevailing sealed (insulated) pores is regarded as heat-insulating. The thermal conductivity of such foam glass depends on a ratio between the solid and the gaseous phase. Since the pore part in foam glass exceeds 90% and thermal conductivity of gases is low, thermal conductivity of glass simply cannot be high. Furthermore, it should be taken into account that certain rarefaction exists in the foam-glass pores, which lowers thermal conductivity even more.

However, thermal conductivity of gases significantly depends on the heat transfer method. As soon as convective flows emerge in the gas medium, thermal conductivity sharply grows. Accordingly, a closed-pore structure in which numerous close pores are divided by thin glass walls seems preferable to a structure with large interconnected pores, even though a coarse-pore sample has lower density. Accordingly, it cannot be stated that the lower density, the lower thermal conductivity is. Such dependence exists in the general case, but it is not unique.

At present, a high level of heat-shielding properties is achieved in the best brands of industrial foam glass. Its thermal conductivity is 0.05 – 0.07 $W/(m \cdot K)$. However, foam glass keeps being upgraded by means of improving is thermophysical properties. In this aspect, several requirements imposed on glass and foaming agents can be stated. To obtain a material with high heat-insulating characteristics, glass should have low viscosity and surface tension in the frothing temperature interval, should not have a tendency to crystallization, and should have a high oxidizing potential, furthermore, glass should be finely milled. Glass powder currently used for foam glass should has specific surface area at least 1500 m^2/kg. Gas emission of the cellulating agent should occur within a certain temperature interval, when glass is already densely sintered, and should not be too intense, to avoid breaking pore walls. The degree of dispersion of the cellulating agent should be higher than the dispersion of glass. The specific surface area of such powder can reach 10,000 m^2/kg and more. A low content of the pore-forming agent (a fraction of percent) results in its particles being separated from each other by glass, and microscopic sizes lead to the formation of numerous fine closed pores.

Lately, a “cold” technology of foam glass production is actively implemented. A typical feature of this method is absence of thermal treatment. All synthesis takes place at room temperatures. It is based on chemical reactions between water glass and fine aluminum powder. One of the products of this reaction is gaseous hydrogen, its emission leads to the formation of numerous gas bubbles in water glass bulk. A simultaneous consequence of this reaction is solidification of water glass. The absence of thermal treatment makes his method very attractive, since it is easy to organize foam glass production right on the site of installation of construction units. However, this method has serious drawbacks: first, the presence of combustible hydrogen is very dangerous in the case of a fire breaking out, second, it is difficult to make the foam glass structure homogenous. Solidification of water glass in the zone of its contact with aluminum does not allow for uniform distribution of the latter and, consequently, prevents getting a uniform structure.

The evolution of this technology will probably evolve take the direction of retarding the foaming reaction. It is necessary to search for additives, which might for a while delay a reaction between water glass and aluminum, allow for their uniform mixing, and only after that “switch on” the reaction.

In the new century the mankind should justly appreciate the merits of foam glass, which is a wonderful material with a set of unique properties and capable of many years of effective service.